Annotated Bibliography of TABS-MD Numerical Modeling System

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Apicella, Guy, Norris, Robert, Newton, Johanna, Ewald, Walter, Forndran, Angelika. (1994). East River Modeling Of Water Quality For Multiple-Project Assessments", Proceedings of the 3rd International Conference on Estuarine and Coastal Modeling III, Oak Brook, IL. American Society of Civil Engineers, New York, 235-248.

The East River Model (ERM), which employs the RMA-2V hydrodynamic and RMA-4 water quality modeling code, was used by Lawler, Matusky & Skelly Engineers to assess water quality impacts in conjunction with a number of programs administered by the New York City Department of Environmental Protection. The two modeling applications described in this paper relate to (1) combined sewer overflow (CSO) effects on dissolved oxygen (DO) and total coliform concentrations, and (2) water pollution control plant (WPCP) effluent dilution as related to whole effluent toxicity (WET) criteria. Two dye surveys at each of the city's six WPCPs revealed that the effluent is well mixed vertically at relatively short distances from the outfall. The ERM was used to simulate the effect of the city's 239 CSO outfalls on DO and total coliform within the East River system and thereby develop a plan for CSO abatement.

Athow, R. F., Berger, R. C., Heltzel, S. B., and Trawle, M. J. (1986). Predicting Maintenance Dredging Requirements: A Case Study, Thimble Shoal and Elizabeth River Channels, Norfolk, Virginia, USA. XIth World Dredging Congress, Brighton, United Kingdom, March 4-7, 1986. J. H. Volbeda, V. L. van Dam, N. Oosterbaan, ed., Central Dredging Association, Delft, The Netherlands, Section A, Part A2, Paper a, 19-33.

Describes how the TABS-2 numerical modeling system was used to study proposed channel and anchorage improvements for Norfolk Harbor. The noncohesive mode of the numerical sediment model (STUDH) was used for the Thimble Shoal Study and the cohesive mode applied to the Elizabeth River study. In both studies the finite element hydrodynamic model RMA-2V was used. Describes procedures used, noting determination of shoaling rates.

Athow, Robert F., Jr., Trawle, Michael J., and Richards, David R. (1987). Numerical Evaluation Of Training Structures. Hydraulic engineering: Proceedings of the 1987 National Conference, Williamsburg, VA, August 3-7, 1987. American Society of Civil Engineers, New York, 345-350.

A technique to evaluate estuarine training structure performance in reducing localized maintenance dredging requirements using the US Army Corps of Engineers TABS-2 numerical modeling system is presented. An application of the two-dimensional, vertically averaged numerical model is demonstrated with emphasis on high-resolution computational grids and sediment transport. A short reach of the Columbia River estuary is simulated in the numerical model. The modeled reach includes four spur dikes constructed to reduce shoaling in the adjacent navigation channel. Using the model, shoaling rates are predicted in the navigation channel with the dikes in place and then with the dikes removed.

Berger, R. C. Jr. (1990). Channel Maintenance By Training Structures: Guidance For Numerical Model Mesh Development, Technical Report HL-90-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Training structures used to control channel currents and sedimentation, which in the past were designed by rules of thumb, are now frequently the subject of numerical model investigations. The precision and stability of numerical models representing the shallow-water equations and transport generally are strongly influenced by the nature of the computational mesh upon which the calculations take place. This condition is amplified by the presence of man-made structures in the flow. It is therefore imperative that mesh development in the vicinity of these structures be guided so that accurate and reliable shoaling predictions result.

This report uses a series of simple linear model equations applied in a finite element framework to develop guidance for the minimum mesh expansion rate, orientation, skewness, oscillation suppression, and bathymetric effects. While this effort was aimed at the TABS-2 modeling system, the findings are generally applicable to other finite element and finite difference models. Appendix A discusses the elimination of oscillations in the TABS-2 program.

Berger, R. C. (1990). Mass Conservation In The RMA2V Code. Hydraulic Engineering: Proceedings of the 1990 National Conference, San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 873-878.

This paper discusses the RMA2V hydrodynamic code with a particular interest in mass conservation problems. These originate from at least two sources. One of which is the slip flow boundary specification in which the boundary slopes are not continuous and the second is due to the formulation itself. The severity of these problems is estimated and recommendations made to improve the model behavior.

Berger, R. C., McAdory, R. T., Martin, W. D., and Schmidt, J. H. (1995). Houston-Galveston Navigation Channels, Texas Project; Report 3: Three-Dimensional Hydrodynamic Model Verification, Technical Report HL-92-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report describes the verification results of the three-dimensional (3-D) hydrodynamic model used to evaluate tides, current velocities, and salinities in Galveston Bay, Texas. This is the third in a series of reports concerning the Houston-Galveston Navigation Channels. The goal of these reports is to determine the effect of the proposed channel deepening and widening upon tides, currents, salinities, and navigation. Report 1 describes the field data collection and results, Report 2 presents the two-dimensional numerical modeling of hydrodynamics for a navigation study, Report 3 presents the verification description for the 3-D model, and Report 4 details the results of tests of the 3-D model.

This report first describes the 3-D model program, RMA10-WES, which is a finite element code using mixed quadratic and linear Lagrange polynomials. The remainder of the report reveals the demonstration of the model applicability through the verification procedure. This procedure of adjustment and verification was first a comparison to a short series of data with a series of adjustments in bed roughness. Then the model was run with no adjustment over a period of roughly 6 months in comparison to field data from 19 July 1990 to 15 January 1991. This period includes the time following a major flood in the

Galveston Bay system for which the model reproduces the timing and magnitude of the salinity rebound very well. Comparisons of model performance are drawn qualitatively between the model and description of the Bay in the literature, and also quantitatively with the field data recorded for this study.

Berger, R. C., Jr., Heltzel, Samuel B., Athow, Robert F., Jr., Richards, David R., Trawle, Michael J. (1985), Norfolk Harbor And Channels Deepening Study; Report 2, Sedimentation Investigation; Chesapeake Bay Hydraulic Model Investigation, Technical Report HL-83-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents the sedimentation findings from combined physical and numerical model tests (hybrid modeling) of deepening the approach channels to Norfolk and Newport News, VA. Because of the varying nature of shoaled material along the project navigation channel, the tests included two separate numerical sediment transport models, which were referred to as the Thimble Shoal model and the Elizabeth River model. The sediment along the Thimble Shoal portion of the navigation channel consists predominantly of noncohesive material while the sediment along the Elizabeth River portion of the navigation project consists primarily of clays and silts. Sedimentation in a third portion of the overall project, referred to as the Atlantic Ocean Channel, was evaluated analytically without using a numerical sediment transport model.

Based on sedimentation results from the Elizabeth River numerical model, the increase in shoaling caused by channel deepening as proposed will be 23 percent. The distribution of shoaled material will not be significantly altered, other than a slight increase in skewness toward the downstream end.

Based on sedimentation results from the Thimble Shoal numerical model, the increase in shoaling caused by channel deepening as proposed will be about 20 percent. The distribution of shoaled material will be slightly altered in that both the upper and lower channel shoaling peaks which presently exist will tend to migrate even more toward the ends of the dredged channel.

Based on the analytic analysis, the estimate of shoaling for the new Atlantic Ocean Channel is about 200,000 cu yd annually.

Berger, R. C., McAdory, Robert T., Schmidt, Joseph H., Martin, William D., and Hauck, Larry H. (1995). Houston-Galveston Navigation Channels, Texas Project; Report 4, Three-Dimensional Numerical Modeling Of Hydrodynamics And Salinity, Technical Report HL-92-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report describes the testing program conducted to evaluate the impact of enlargement of the Houston-Galveston Navigation Channel on the salinity and hydrodynamic fields of tidally influenced Galveston Bay. The present channel nominal dimensions are 40 ft deep at mean low water (mlw) and 400 ft wide. The proposed enlargements tested are for a channel 45 ft deep at mlw and 530 ft wide (Phase I) and 50 ft deep and 600 ft wide (Phase II). Current plans do not include the Phase II enlargement. Salinity fields for these channel configurations and the existing channel dimensions are compared. In a separate study the results from these simulations were used to drive an ecosystem model to predict oyster production.

Testing conditions included tidal conditions and winds for the year 1984. The freshwater inflows (developed outside this study) were tested for

low-, medium-, and high-flow years. Additionally, since water demand in the future is expected to modify freshwater distribution and quantities, future distributions for the test year 1999 (Wallisville Dam in place), 2024, and

The code used (RMA10-WES) is a Galerkin-based finite element solution to simulate three-dimensional (3-D) unsteady open-channel flow. The code represents 3-D hydrodynamics using conservation of fluid mass, horizontal momentum, and salinity/temperature transport equations subject to the hydrostatic assumption.

Results of these tests showed that the largest increases in salinity were in low-salinity areas, including the upper west side of the bay across the channel from Atkinson Island, and the upper bay channel. Trinity Bay showed a small salinity increase. South of midbay the salinity increases were generally less than 1 ppt. Some locations in the south bay near the navigation channel occasionally showed a decrease in salinity for the deeper channel configurations. These decreases occurred during the period of rebound in salinity after the high inflow period of late spring.

The deepened channels showed increased salinity stratification. The stratification increased with channel project depths and with freshwater inflow in the Buffalo Bayou/San Jacinto River Basin.
The future hydrologic scenarios result in more freshwater inflow to Galveston Bay through Buffalo Bayou and San Jacinto River. The deepened channels typically resulted in less significant salinity increases in the scenarios than for the present hydrologic year (1990). These future scenarios redistribute some of the freshwater inflow from the Trinity River and reintroduce it through Buffalo Bayou and San Jacinto River. The model indicates a corresponding increase in salinity in Trinity Bay and decrease in the eastern upper bay salinity.

Berger, R. C., and Stockstill, R. L. (1995). Finite-Element Model for High-Velocity Channels, Journal of Hydraulic Engineering, American Society of Civil Engineers, ISSN 0733-9429/95/0010-0710-0716.

Numerical modelers of high-velocity channels are faced with supercritical transitions and the difficulty in capturing discontinuities in the flow field, known as hydraulic jumps. The implied smoothness of a numerical scheme can produce fictitious oscillations near these jump locations and can lead to instability. It is also important that the discrete numerical operations preserve the Rankine-Hugoniot conditions and accurately model jump speed and location. The geometric complexity of high-velocity channels with bridge piers and service ramps are easily represented using an unstructured model. A two-dimensional finite-element model that utilizes a characteristic based Petrov-Galerkin method and a shock-detection mechanism, which relies on elemental energy variation results in a robust system to model high-velocity channels. Comparisons are made between analytic shock-speed results, published laboratory data of a lateral contraction, and with a more general physical model.

Berger, R. C., and Stockstill, R. L. (1994). Considerations in 2-D Modeling of Hydraulically Steep Flow, Proceedings of the 1994 National Conference on Hydraulic Engineering, American Society of Civil Engineering.

Simplifications in the equations used to describe shallow water flow lead to some difficulties in modeling supercritical flow. The hydrostatic assumption produces two significant differences from the actual flow, in that the model s wave celerity is too large and that the energy associated with vertical motion

is dissipated instantly. These differences lead to standing waves that protrude into the flow at a greater angle than those produced by the actual flow and a tendency to dissipate succeeding waves too quickly.

Berger, R. C., and Stockstill, R. L. (1993). A 2-D Numerical Model for High Velocity Channels, Proceedings of the 1993 National Conference on Hydraulic Engineering, American Society of Civil Engineers.

The hydraulic performance of a high velocity channel depends on maintaining a supercritical flow regime over specified portions of its length. Predicting the potential location of shocks such as oblique standing waves and hydraulic jumps and determining the super-elevation of the water surface in channel bends is necessary to design the required wall heights. Work is being conducted to develop a numerical flow model that can estimate the location and velocity channels. The high velocity channel model, HIVEL2D, is a depth averaged two-dimensional (2-D) flow model designed specifically for flow fields containing supercritical and sub-critical regimes as well as the transitions between the regimes. This paper summarizes the numerical scheme and presents some of the initial test results of HIVEL2D, currently under development at the U.S. Army Engineer Waterways Experiment Station.

Berger, R.C. (1994). A Finite Element Model Application to a Study of Circulation and Salinity Intrusion in Galveston Bay, Texas, Finite Elements in Environmental Problems.

No Abstract

Cheramie, Kirk. (1995). Hydrologic Modeling Of Fresh Water Resources. Coastal Zone: Proceedings of the Symposium on Coastal and Ocean management, Tampa, FL. American Society of Civil Engineers, New York, 294-295.

This paper specifically identifies the TABS-MD model designed by the U.S. Army Corps of Engineers, Waterways Experiment Station as an effective management tool for efficiently supplying raw fresh water resources to coastal communities. Through the use of the TABS-MD computer model, the Bayou Lafourche Fresh Water District, a state political sub-district, is able to adequately supply fresh water to eight percent of the population of Louisiana. The model incorporates boundary conditions such as tidal range, stage, velocity and constituent concentrations within Bayou Lafourche, a 110 mile fresh water channel between the Mississippi River and the Gulf of Mexico. By setting boundary conditions and executing the model, management can decide upon the quantity of fresh water that must be pumped into Bayou Lafourche at its headwaters in order to regulate salinity concentrations at fresh water intakes at its southern most locations. By accurately determining the amount of fresh water required to offset saltwater intrusion, the expenditure of public tax dollars on electricity and fuel for fresh water pumps are better estimated, yielding savings to the public while at the same time insuring an adequate fresh water supply.

Coleman, Wesley E., Jr. (1992). A Chesapeake Bay Field Modeling And Monitoring Projects. Coastal engineering practice 1992, Long Beach, CA, March 9-11, 1992. American Society of Civil Engineering, New York, 221-233.

'Traditional' erosion control measures often do not meet the Corps of Engineers' requirement for economic justification. The costs of these measures are much greater than the benefits provided. The costs are also prohibitive to property owners seeking shoreline protection. The Chesapeake Bay Shoreline Erosion Study has provided information for designing offshore breakwaters more cost-

effectively to encourage implementation of these measures in the interest of Bay-wide improvement. Offshore breakwaters were installed at two locations in the Bay, and their performance was monitored.

Comes, Bradley M., Copeland, Ronald R., and Thomas, William A. (1989). Red River Waterway, John H. Overton Lock and Dam; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation, Technical Report HL-89-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from the John H. Overton Lock and Dam on the Red River Waterway, Louisiana. The numerical model was used to evaluate the effects of various design changes on fine sediment deposition. These included changing the length and height of divider dikes, the number of openings on the ported guard wall, the invert elevation in the lock approach channel, and the location of spur dikes.

Copeland, Ronald R., and Thomas, William A. (1988). Red River Waterway Sedimentation Study Downstream From Lock and Dam No. 1; Numerical Model Investigation, Technical Report HL-88-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The effect of recently constructed and proposed channel improvements on sedimentation in the Red River downstream from Lock and Dam No. 1 were investigated. A one-dimensional numerical model (HEC-6) was used to evaluate the effect of contraction works on dredging requirements in the navigation channel. A two-dimensional numerical model (TABS-2) was used to evaluate proposals to reduce deposition in the downstream lock approach channel at Lock and Dam No. 1. Recommendations were made to reduce sediment problems in the study reach.

Copeland, Ronald R., Comes, Bradley M., and Thomas, William A. (1991). Red River Waterway, Lock and Dam No. 3; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation, Technical Report HL-91-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from Lock and Dam No. 3 on the Red River Waterway, Louisiana. The numerical model was used to evaluate the effects of various design changes on fine sediment deposition. These included the cross-section shape in the upstream lock approach channel, the distance between the lock wall and the first spillway gate, the number of openings in the ported guard wall, and location of a berm in the upstream channel.

Copeland, Ronald R., Heath, Ronald E., and Thomas, William A. (1990). Red River Waterway, Lock and Dam No. 4; Report 5, Sedimentation In Lock Approaches; TABS-2 Numerical Model Investigation, Technical Report HL-90-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A two-dimensional numerical model, TABS-2, was used to predict fine sediment deposition in the lock approach channels upstream and downstream from proposed Lock and Dam No. 4 on the Red River Waterway, Louisiana. The numerical model was used to evaluate alternative designs. Fine sediment deposition with the proposed design at Lock and Dam No. 4 was compared to fine sediment deposition at existing locks and dams downstream.

Copeland, Ronald R., Combs, Phil, and Little, Charles D. (1989). Application Of 2-D Model To Reduce Sedimentation Problems. Sediment Transport Modeling: Proceedings of the International Symposium, New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 124-129.

The Corps of Engineers opened Lock and Dam No. 1 on the Red River Waterway in 1984. During the first runoff season, excessive quantities of fine sediment deposited in both the upstream and downstream lock approach channels. Two-dimensional numerical model studies using the TABS-2 computer programs were conducted to determine remedial measures to significantly reduce hydraulic dredging, especially in the vicinity of the lock miter gates. This paper addresses the studies and evaluates the effectiveness of the construction measures.

Deering, Michael K. (1990). Practical Applications of 2-D Hydrodynamic Modeling. Hydraulic Engineering: Proceedings of the 1990 National Conference, San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 755-760.

Two-dimensional hydrodynamic modeling capability has greatly impacted the hydraulics community and significantly altered the approaches to design and analysis of open channel systems. Two-dimensional modeling has the potential for eliminating over simplified assumptions associated with one-dimensional modeling. In some cases it may negate the need for physical model studies. Five case studies that employed two-dimensional hydrodynamic methods are presented.

Demissie, Misganaw, Soong, David, and Bhowmik, Nani G. (1988). Hydraulic Study For The Construction Of Artificial Islands In Peoria Lake, Illinois. Hydraulic engineering: Proceedings of the 1988 National Conference on Hydraulic Engineering, Colorado Springs, CO, August 8-12, 1988. American Society of Civil Engineers, New York, 340-345.

Long-term sediment accumulation in the lake reduced the average depth of the lake from 8 feet in 1903 to 2.6 feet in 1985, which resulted in the deterioration of aquatic habitats and recreational areas in the lake. A detailed hydraulic analysis was needed to evaluate the feasibility creating islands in Peoria Lake. The major hydraulic considerations include determining the optimum locations for the islands in terms of minimizing the sedimentation rates around the islands. A hydraulic study was conducted to investigate the best locations for constructing islands in the lake. The study made use of the one-dimensional HEC-6 sediment transport model and the two-dimensional TABS-2 hydrodynamic model. Field data were also collected to establish existing lake-bottom profiles and velocity distributions at selected locations.

Donnell, Barbara Park, and Letter, Joseph V. Jr. (1992). The Atchafalaya River Delta, Report 12, Two-Dimensional Modeling Of Alternative Plans And Impacts On The Atchafalaya Bay And Terrebonne Marshes, Technical Report HL-82-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Wax Lake Outlet and Atchafalaya River deltas in Louisiana have grown dramatically, and concern over the impact of this growth has led the US Army Corps of Engineers to conduct an investigation to predict how the deltas will evolve over the next 50 years. An additional task was to determine the impacts of that growth on navigation, flood control, salinity, and sedimentation in the bay area. The technical approach for this investigation builds upon the TABS-2

finite element numerical modeling system and is fully described in Report 11 of this series. Comparisons of the existing condition results with various alternatives are presented. In summary, the extension of the Avoca Island Levee to Deer Island (Reach 2) resulted in an approximate 8 percent increase in the predicted size of the 50-year delta evolution regardless of other constraints tested. For all alternatives tested, the size of the 50-year subaerial delta fell within the bounds of 56 to 144 square miles. The most extreme delta evolution simulation tested was the condition without the Wax Lake Outlet flow control project, no navigation channel dredging, and no levee extension. For all delta evolution simulations tested, the water surface elevations within area east of the levee increased from 3.4 to 6.0 ft by year 2030. In each case tested, the Avoca Island Levee Extension to Reach 2 decreased the backwater effect of the 50-year delta by approximately 2 ft.

Donnell, Barbara Park, Letter, Joseph V. Jr., and Teeter, Allen M. (1991). The Atchafalaya River Delta, Report 11, Two-Dimensional Modeling, Technical Report HL-82-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Wax Lake Outlet and Atchafalaya River deltas in Louisiana have grown dramatically, and concern over the impact of this growth has led the US Army Corps of Engineers to conduct an investigation to predict how the deltas will evolve over the next 50 years. The goal was to design a series of modeling tools capable of predicting delta evolution and the impacts of that growth on navigation, flood control, salinity, and sedimentation. The technical approach for this investigation was built upon the TABS-2 finite element modeling system. The fully two-dimensional models for hydrodynamics, salinity, and sediment transport were first verified to extensive prototype data, the employed to predict delta evolution for existing conditions at years 1980, 1995, 2010, and 2030 within the project area. Subsidence estimates for the system were made by regression of historical water-surface elevation gaging stations.

Donnell, Barbara Park, and Letter, Joseph V. Jr. (1992). The Atchafalaya River Delta, Report 13, Summary Report Of Delta Growth Predictions, Technical Report HL-82-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Coastal Louisiana is experiencing dramatic and alarming land loss. The exception to this general trend is the Atchafalaya River delta, which has been experiencing dramatic deltaic growth during the past 20 years. This deltaic activity can be viewed as both a resource for development of coastal wetlands and as a threat for potentially aggravating flooding in communities upstream of the delta. In response to these concerns, the Corps of Engineers is conducting a thorough investigation to predict how the delta will evolve over the next 50 years, the impacts of the growth and the effectiveness of structures for controlling detrimental results. The investigation approach used several analytical and numerical techniques applied separately to arrive at independent predictions of delta growth. The approach was arranged to provide results from increasingly sophisticated techniques over the period 1980-1989. Each of the techniques are summarized and comparisons are made. The techniques included: analytical model, regression/extrapolation analysis of past behavior, generic analysis of similar delta’s growth patterns, a quasi-two-dimensional numerical model, and TABS two-dimensional numerical model. The results from these techniques indicated a wide possible range of 32 to 149 square miles of sub-aerial delta for year 2030. A regression analysis of all of these results predicted the sub-aerial delta area to peak at year 2035 with 89 square miles.

Evans, Robert A. (1992). Lockwoods Folly Numerical Circulation Study, Technical Report HL-92-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The region around Lockwoods Folly River and Inlet, North Carolina, has experienced increased development in the past 50 years. In addition, the inlet has been changed by the addition of the Atlantic Intracoastal Waterway (AIWW). There have been concerns that the circulation is not sufficient to maintain good water quality. These concerns led the US Army Corps of Engineers to conduct an investigation to determine the effect of the AIWW on overall circulation patterns. The technical approach for this investigation was built upon the TABS-MD finite element modeling system. The two-dimensional model for hydrodynamics was first validated to limited prototype data, then used in conjunction with the transport model to predict the changes in tracer levels between the base condition and three plan conditions.

Fagerburg, T. L. (1990). Mississippi River-Gulf Outlet, Louisiana, Field Data Report, Technical Report HL-90-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Water levels, current speeds and directions, salinities, and suspended sediment concentrations were measured in the Mississippi River-Gulf Outlet Canal, New Orleans, LA, in October and November 1988. The prototype data were collected as part of a study to incorporate these data in a numerical model for determination of shoaling rates. This report describes the equipment and procedures used in the data acquisition and presents tables, plots, and summaries of all the data collected.

Attempts to correlate ground truth suspended sediment data with the satellite data were unsuccessful due to cloud cover during the periods data were obtained.

Fischenich, J. Craig. (1990). Cumulative Impacts Analysis On A Midwest Fluvial System. Hydraulic Engineering: Proceedings of the 1990 National Conference, San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 802-807.

The US Army Corps of Engineers recently completed an analysis of the cumulative impacts of erosion control structures on the Platte River in Nebraska. This was done in response to concerns about the effects of bank stabilization activities upon threatened and endangered species that use the Platte River. Physical changes to the river generated by existing and proposed bank stabilization activities were evaluated to determine the environmental significance of various bank stabilization structures. HEC-6, a one-dimensional sediment transport model, was used to quantify cumulative impacts from bank stabilization activities for the entire river. TABS-2, a two-dimensional sediment transport model, was used to quantify local impacts from a variety of structures.

Ford, R. Glenn, Sobey, Rodney J., Shrestha, Parmeshwar L., Saviz, Camilla M., Orlob, Gerald T., King, Ian P. (1993). San Francisco Bay and Delta Oil Spill Fate Studies. Part II: Oil Spill Simulation. Proceedings, National Conference on Hydraulic Engineering, San Francisco, CA. American Society of Civil Engineers, New York, 641-646.

Because of the presence of oil refineries and significant tanker and barge traffic in the bay and delta region, the possibility of a moderate or major spill in the area must be considered. We have constructed a general model that calculates a Lagrangian element solution for an oil spill in this region.

Surface currents are simulated using output from the U.C. David RMA-2V model. We combine the surface current fields with real time sequences of wind speed and direction collected at eight sites in the bay and delta areas during 1990 and 1991 interpolated to form a smooth spatially varying wind field. A random diffusive component is added to simulate spreading. The magnitude of the diffusive component and the number of Lagrangian elements are adjusted to simulate spills of varying sizes. Characterization of intertidal substrates in this area is based on 1:24,000 scale digital maps and the National Wetlands Inventory. Oil particles are not permitted to cross exposed mud or marsh, or they are assumed to strand if they are already over these substrates as the tide ebbs. The model is written in ANSI FORTRAN77 and runs in protected mode on a 486 based PC. It includes high resolution runtime graphics and an interactive interface that permits the user to pause and query the model.

Freeman, Gary, and Weissinger, Lisa. (1991). TABS-2 Application To Kawainui Marsh Flood Control. Proceedings of the 1991 National Conference on Hydraulic Engineering, Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 292-297.

The TABS-2 mathematical modeling system was used to evaluate the effectiveness of alternatives designed to eliminate flooding problems in the Kawainui Marsh located in Kailua on the east side of the island of Oahu, Hawaii. The study required unique applications of the TABS-2 modeling system. The verification required altering the numerical code to model free flow over the existing Federally constructed flood control levee which overtopped during the 31 December 1987 storm event and caused extensive damage to the community of Coconut Grove. One of the alternative plans consisted of placing a series of 15 culverts in the existing levee in order to drain the marsh floodwaters into an extension of the Oneawa channel and release them into the Pacific Ocean. This alternative required the addition of culvert modeling capability to the TABS-2 numerical code. These two applications were further exacerbated by the requirement to use dynamic flow simulations in order to accurately model the effects of various hydrographs. The modeling techniques employed and various model results are presented.

Granat, Mitchell A., and Brogdon, Noble J. (1990). Cumberland Sound and Kings Bay Pre-Trident and Basic Trident Channel Hydrodynamic and Sediment Transport Hybrid Modeling; Volume I: Main Text and Appendixes A, C, and D, Technical Report HL-90-21, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A previously verified hybrid modeling system (coupled physical and numerical models) of the Kings Bay/Cumberland Sound estuarine system was used to investigate hydrodynamic and sedimentation variations associated with Trident channel expansion. The models generally demonstrated small velocity differences between the pre-Trident base channel condition and the enlarged Trident channel condition tested. Reduced velocity magnitudes in the deepened upper Kings Bay turning basin demonstrated the largest base-to-plan velocity differences.

Subtle circulation differences were identified. The deepened and widened Trident plan channel increased flood and ebb volume transport efficiency of the submarine channel through St. Marys Inlet into Cumberland Sound and Kings Bay. Increased discharge through the past Kings Bay changed the phasing relationships north of Kings Bay.

Although not an explicit objective of the modeling efforts, tidal effects were examined. The tested plan condition resulted in higher high water and midtide level elevations in both the physical and numerical models. Variations were

close to, but greater than, model detection limits. Low-water elevations between the models were inconsistent. Based on more recent field data, it was concluded that tide range will probably not change as a result of Trident channel improvements, and mean water level in Cumberland Sound may increase a small amount, less than the normal annual variation in mean sea level.

The subtle base-to-plan hydrodynamic differences and the increased plan channel areas resulted in dramatic sedimentation responses. The numerical model predictions indicated a 150 percent increase in required annual plan channel maintenance dredging. Based on previous shoaling history and this study's findings, the typical annual plan channel maintenance dredging requirement is predicted to vary from a low of about 0.9 million cubic yards per year to a high of about 4.9 million cubic yards per year. The long-term average submarine channel maintenance is predicted to increase from approximately 1.0 million cubic yards per year for pre-Trident channel conditions to approximately 2.5 million cubic yards per year for the Trident channel condition.

Granat, Mitchell A., Brogdon, Noble J., Cartwright, John T., and McAnally, William H., Jr. (1989). Verification Of The Hydrodynamic And Sediment Transport Hybrid Modeling System For Cumberland Sound and Kings Bay Navigation Channel, Georgia, Technical Report HL-89-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
A hybrid modeling system (coupled physical and numerical models) was developed to investigate the hydrodynamic and sedimentation processes of Cumberland Sound and the interior Kings Bay navigation channel. The hybrid modeling procedures and the physical and numerical model verifications are described in detail.

The Kings Bay physical model was an accurately scaled fixed-bed concrete model of the Cumberland Sound/Kings Bay estuarine system. The physical model provided the means of assessing three-dimensional hydrodynamic characteristics of Cumberland Sound and Kings Bay. It also provided the boundary forcing conditions for the numerical model and an expanded database for comparison. Verification of the physical model to reproduce pre-Trident channel field measurements collected during November 1982 and transitional channel conditions measured during January 1985 was demonstrated.

The other component of the modeling system was the US Army Corps of Engineers Generalized Computer Program System: Open-Channel Flow and Sedimentation, TABS-2. TABS-2 is a complete depth-averaged finite element numerical modeling system. The numerical hydrodynamic model RMA-2V used physical model-derived St. Marys Inlet water levels and tributary velocity measurements for the boundary forcing conditions for an average tidal cycle. The numerical model was verified to physical model tidal elevations and depth-averaged velocity data for interior locations.

A wetting and drying algorithm was used to numerically model the extensive marsh and inter-tidal areas of the estuarine system. Marsh-estuarine circulation interaction and prescribed marsh elevation were found to be important in achieving proper hydrodynamic reproduction. Three separate numerical model schematizations or meshes of the Cumberland Sound system were verified as the submarine channel evolved in detail. RMA-2V demonstrated reasonable reproduction of pre-Trident and transitional channel hydrodynamic conditions for the Cumberland Sound/Kings Bay system.

Hydrodynamic results from RMA-2V were used in the numerical sediment transport code STUDH in modeling the interaction of the flow transport and sedimentation on the bed. Both cohesive (clay and silt) and noncohesive (silt and sand)

sedimentation were modeled. STUDH was verified through comparisons of model predictions with actual field shoaling rates. Excellent numerical model pre-Trident channel sediment verification was demonstrated. Model predictions for the upper Trident channel turning basin for the transitional channel demonstrated higher shoaling rates than the limited field data. Possible explanations for this difference included low field sediment loads associated with the prolonged east coast drought, the transitional nature of the channel, and the possible need for further model adjustments. The sediment model was developed and verified for long-term average conditions, and additional model adjustments could not be justified based on the limited transitional channel data.

Verification of the hydrodynamic and sediment transport hybrid modeling system for Cumberland Sound and Kings Bay navigation channel has been demonstrated. The developed modeling procedures can be used in carefully designed testing programs to assess potential hydrodynamic and sedimentation impacts associated with submarine plan channel and remedial measure alternatives.

Hall, Brad R., and Engel, John (1995). Modeling Of Sedimentation Processes In A Bottomland Hardwood Wetland. Proceedings, International Water Resources Engineering Conference, San Antonio, TX. American Society of Civil Engineers, New York, 1, 94-98.

For several years, the US Army Engineer Waterways Experiment Station has monitored several physical and biological parameters on the Rex Hancock Swamp on the Cache River for ecosystems modeling purposes. Measurements of suspended sediment grain size, concentration, and deposition quantities within the wetland system were obtained. Boundary conditions and overall sediment budget for the wetland were identified by sampling daily suspended sediment loads at the upstream and downstream limits of the wetland system. The data obtained were then used to develop and test a TABS-MD numerical model of the wetland system.

Hauck, Larry M. (1992). Hydrodynamics At Mouth of Colorado River, Texas, Project; Numerical Model Investigation, Technical Report HL-92-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Mouth of Colorado, Texas, Project includes a diversion channel of the Colorado River into the eastern arm of Matagorda Bay, a dam on the present Colorado River channel downstream of the diversion channel, a dam at Culver Cut, and a navigation bypass channel from the Gulf of Mexico to the city of Matagorda, TX. The project will create an intersection of the Gulf Intracoastal Waterway (GIWW) with the navigation bypass channel, which is the emphasis of this study. The freshwater flow diversion is expected to alter existing current patterns and tidal propagation in an area with navigational and recreational concerns.

The US Army Engineer District, Galveston, required that preliminary results from steady-state numerical simulations be produced initially and be followed by field investigations and long-term dynamic numerical simulations of hydrodynamics. Both the field data collection effort and the ship simulation study are described in separate reports.

This report describes the hydrodynamic steady-state preliminary results, verifications to prototype measurements, and long-term tidally influenced simulations using the vertically integrated two-dimensional numerical model, RMA-2V.

Hauck, Larry M., and Brown, Ben, Jr. (1990). Numerical Modeling Of Hydrodynamics, Brazos Island Harbor Project, Texas (Brownsville Ship Channel), Technical Report HL-90-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Brazos Island Harbor Project, south Texas, has been authorized for navigation channel improvements, which include deepening the Brownsville Ship Channel. A vertically integrated two-dimensional numerical model RMA- 2V is being used to simulate the Brownsville Ship Channel and the lower Laguna Madre. RMA-2V was used to produce the hydrodynamics (water levels and velocities) for existing and three alternative channel designs. These hydrodynamic conditions were used in a ship simulator study. Historical velocity (direction and speed) measurements taken at approximately hourly intervals during the period 15-18 July 1980 at several stations were used to verify RMA-2V. Water level measurements from 4 tide gages were available for the same period to facilitate model verification. Because the Laguna Madre exhibits large response to wind forcing, some of the inaccuracies in water level verification were suspected to be the result of the sparsity of wind speed and direction data in the prototype system for the model verification. The verified RMA-2V model was operated with a high amplitude diurnal (spring) tide with a temporally varying southeast wind at 4 to 20 mph. The wind was phased to increase both the ebb and flow velocities. With these tidal and wind conditions, RMA-2V simulated the hydrodynamics for existing and 3 alternative channel designs. The peak ebb and flood currents for each design were saved as computer files for use in a separate ship simulator study.

Hauck, Larry M., Teeter, Allen M., Pankow, Walter, and Evans, Robert A., Jr. (1990). San Francisco Central Bay Suspended Sediment Movement; Report 1, Summer Condition Data Collection Program And Numerical Model Verification, Technical Report HL-90-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Field data were collected on currents, salinities, and suspended sediments intensively over a lunar day and sporadically over a fortnight in September 1988 for the purpose of identifying transport processes and conditions in central San Francisco Bay and for numerical model verification. Conditions were typical of a low freshwater inflow summer season in this area. A two-dimensional horizontal finite element model was applied and verified to field and physical hydraulic model data. The model is intended for future long-term studies of the fate of dredged material dispersed from the Alcatraz disposal site.

Heath, Ronald E., and Copeland Ronald R. (1989). Application Of Two-Dimensional Model To Predict Fine Sediment Deposition. Sediment Transport Modeling: Proceedings of the International Symposium, New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 118-123.

The TABS-2 two-dimensional numerical modeling system was used to predict the potential for fine sediment deposition in the lock approach channels at Lock and Dam Nos. 4 and 5 on the Red River near Shreveport, Louisiana. This paper outlines the numerical modeling study procedure developed during the Red River navigation study with specific application at Lock and Dam Nos. 4 and 5. The paper describes the importance of hydrodynamic boundary conditions, sediment concentrations and sizes, and flow durations. The two-dimensional numerical model was very effective for evaluating specific design alteration and their effect on fine sediment deposition in the upstream an downstream lock approach channels.

Heltzel, S. B. (1985). The Impact Of The I-664 Bridge-Tunnel Crossing On Sedimentation. Hydraulics and hydrology in the small computer age, proceedings of the Specialty Conference, Lake Buena Vista, U.S.A., August 12-17, 1985. W. R. Waldrop, ed., American Society of Civil Engineers, New York, Session 4C, 1, 254-259.

The procedures used to study the effects of a proposed bridge tunnel crossing on sedimentation in the James River estuary, Virginia, U.S.A. are briefly described. A finite element hydrodynamic model, RMA-2V was used for a navigation channel study and a general sedimentation study. The non-cohesive or sand version of the finite element transport models of STUDH was used to investigate the navigation channels and evaluate shoaling changes. The cohesive or clay version was used to study the sedimentation. Details of the simulation studies are presented and no adverse impact of the proposed construction was indicated in the channels or in oyster ground areas.

Heltzel, Samuel B. (1988). I-664 Bridge-Tunnel Study, Virginia; Sedimentation And Circulation Investigation, Technical Report HL-88-25, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents results from physical and numerical model tests on the effects of the proposed I-664 James River Bridge-Tunnel complex on (a) sedimentation in the federally maintained channels (Newport News, Norfolk Harbor, and Elizabeth River), (b) general sedimentation in the lower James River, 8changes in overall flushing characteristics, and (d) changes in current velocities and flushing near the Craney Island disposal site.

The navigation channel sedimentation was evaluated using the TABS-2 finite element numerical models RMA-2V for hydrodynamics and STUDH for sedimentation with an existing numerical mesh of the Elizabeth River and lower James River areas. For the general sedimentation investigation, a new numerical mesh was created and the same numerical models, RMA-2V and STUDH, were used. Data for the flushing and currents evaluation were provided by the Virginia Institute of Marine Science.

Results from the physical model tests indicate circulation changes will be localized with minimal effects on the general circulation of the lower James River.

Results from the numerical sedimentation modeling indicate that sedimentation will be generally unchanged or reduced except on either side of the north island where increases can be expected. The areas experiencing unchanged or slightly reduced sedimentation rates include the oyster grounds, the Elizabeth River and Norfolk Harbor Channels, and the Newport News Channel.

Heltzel, Samuel B., and Granat, Mitchell A. (1988). Lower James River Circulation Study, Virginia; Evaluation Of Craney Island Enlargement Alternatives, Technical Report HL-88-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents results from the numerical model investigation whose primary objective was to assess general changes in circulation, currents, and sedimentation associated with six proposed alternative expansion geometries of the Craney Island confined disposal facility. An additional objective of the study was to assess the effects of each of the six alternative geometries on the

reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point.

This numerical model investigation used the TABS-2 finite element numerical models RMA-2V for hydrodynamics and STUDH for sedimentation with a modified version of an existing numerical mesh of the Lower James River. Other information presently available regarding the estuarine circulation and flow convergence observed off Newport News Point and Hampton Flats was reviewed.

With the exception of the Newport News Channel, results from the numerical hydrodynamic modeling indicated no plan to base velocity differences greater than "0.06 fps at any of the critical areas of interest. Velocity differences greater than 0.10 fps were indicated for the Newport News Channel; channel plan velocities always exceeded base velocities with maximum ebb velocity differences greater than maximum flood velocity differences. Plans with northward extensions resulted in the largest increases. The greatest changes, less than 0.35 fps on ebb and 0.25 fps on flood, were indicated for plans A and B, the largest expansion alternatives also involving westward expansions.

Subtle localized circulation variations, generally within 16,000 ft adjacent to and north and northwest of Craney Island, were identified in base to plan comparison vector plots.

Results from the numerical sedimentation modeling showed that plan to base shoaling index values (plan-predicted sedimentation divided by base-predicted sedimentation) were all within 90 to 110 percent at the critical areas of interest. The Nansemond River entrance was the only area considered to demonstrate any distinct changes in base and plan sedimentation. Considering the existing low sedimentation in the critical areas examined, the indicated differences are well within ordinary field survey detection limits.

Alternatives A, D, and F may impact water quality characteristics as a result of a reduced circulation zone between the Craney Island extension and the mainland.

Appendix A contains general information on the finite element method. A brief description of RMA-2V and STUDH appears in Appendices B and C, respectively.

Heltzel, Samuel B. (1992). Evaluation Of Proposed Port Facilities, Charleston Harbor, South Carolina. Proceedings of Ports '92, Seattle, WA. American Society of Civil Engineers, New York, 791-801.

Often it is necessary for port facility designers to evaluate various alternative development plans for port facilities. These evaluations may include a ship navigability study or an evaluation of potential impacts to channel and facility shoaling and maintenance dredging requirements. A study of this type was performed for the South Carolina State Ports Authority (SCSPA) by the US Army Engineer Waterways Experiment Station. The study was designed to provide a preliminary evaluation of two alternative port facilities. This numerical model investigation used the US Army Corps of Engineers TABS-MD numerical modeling system for open channel flow and sedimentation. Boundary conditions and a verification data set were obtained from the laterally averaged numerical model Fine-Grained Bed Sediment (FIBS). The numerical model mesh used in this study is a comprehensive mesh of the Charleston Harbor system. Verification was very carefully conducted, and a sensitivity analysis was also performed on model parameters. This paper presents the results of this port facility evaluation.

Hewlett, J. Christopher, Daggett, Larry L., and Heltzel, Samuel B. (1987). Ship Navigation Simulator Study, Savannah Harbor Widening Project, Savannah, Georgia, Technical Report HL-87-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The US Army Engineer Waterways Experiment Station (WES) ship simulator was used to evaluate the proposed channel widening of the Savannah Harbor from Fig Island Turning Basin to Kings Island Turning Basin. The widening would extend the north side of the channel 100 ft. The present channel width of 400 ft causes difficulties in the maneuvering of the 950-ft New York Class container ships that began calling in Savannah approximately 2 years ago. For this reason, the simulation study was conducted using a numerical model of this container ship.

To generate channel currents for input into the simulation, a hydrodynamic finite element model of the Savannah Harbor was developed as part of the study. Boundary conditions for this model were obtained from a larger numerical model of the entire Savannah estuary system developed by the WES Hydraulics Laboratory Math Modeling Group. Prior to testing, professional pilots from Savannah conducted a series of runs for the purpose of validating the simulation.

The simulations consisted of existing and planned conditions. Inbound and outbound runs were performed in opposing currents from an extreme tidal range of 10.5 ft. A total of 42 runs were made, 10 outbound runs in the existing channel, 10 outbound runs in the planned channel, 11 inbound runs in the existing channel, and 11 inbound runs in the planned channel. Professional pilots from the Savannah Pilots Association conned the ship during the tests. Study results were based on a basic statistical analysis in which the means and standard deviations of the following maneuvering parameters in the existing and planned channels were compared: rudder angle, rate of turn, heading, revolutions per minute, speed, and clearances to the channel edge. Results of this analysis showed a small but consistent improvement in navigation in the planned channel.

Appendix A presents plots of the current model meshes for both the existing and planned channels. Appendix B shows plots of the current vectors from the finite element model. Appendix C shows all pilot track-lines plotted simultaneously for each test condition. Appendix D presents the pilots' ratings of the simulator and of the proposed channel widening and tabulates these comments.

Holland, J. P., Berger, R. C., and Schmidt, J.H. (1996). Finite Element Analyses in Surface Water and Groundwater: an Overview of Investigations at the U.S. Army Engineer Waterways Experiment Station, Third US-Japan Symposium on Finite Element Methods in Large-Scale Computational Fluid Dynamics, March 31-April 3 1996, Minneapolis, MN.

No Abstract

Jones, Norman L., and Richards, David R. (1992). Mesh Generation For Estuarine Flow Modeling, Journal of Waterway, Port, Coastal and Ocean Engineering, American Society of Civil Engineers, 118(6), 599-614.

A finite element computer modeling system called TABS-2 has been developed by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. TABS-2 has been used to model shallow water flow in estuaries. Accurate modeling of the flow in estuaries using TABS-2 requires the use of very large two-dimensional finite element meshes. The task of constructing such meshes has traditionally been the most time-consuming and error-prone part of the modeling

process. Most automatic mesh-generation schemes are not well suited for estuarine modeling because the regions modeled are typically highly complex and irregular. As a result, the meshes are often constructed manually by coding the mesh in an ASCII file. Manual construction of large meshes is very tedious and can take several weeks to complete. To overcome this difficulty, a mesh generation scheme well suited for estuarine modeling has been developed involving a triangulation algorithm and a variety of mesh editing tools. The scheme makes it possible to generate large meshes of several thousand elements in a relatively short period of time. In addition, the scheme results in meshes with favorable geometric properties, leading to stability and accurate solutions.

Letter, Joseph V., Jr. (1993). Grand and White Lakes Flood Control Project; Numerical Model Investigation, Technical Report HL-93-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Grand and White Lakes flood control project provides protection over a broad portion of the Louisiana coastline. The study area involves a wide variety of wetlands and complex canals and waterways. The area supports many economic interests with potentially conflicting desires for management of the water resources. The project required the capability of quantitatively estimating the relative performance of a large number of design alternatives.

Numerical modeling techniques capable of addressing the flood routing and salinity intrusion processes required to evaluate project alternatives were developed. These techniques included the specification of control structures within the one-dimensional finite element formulation, utilization of marsh porosity, discretization of complex spatial geometric features of the wetlands, and the use of one-dimensional networking in conjunction with the two-dimensional finite element formulation.

Numerical testing was performed for eighteen separate design alternatives for the system. Flood events with 2-, 5-, 10-, 25- and 50-year return intervals were simulated and stage exceedance curves generated. Salinity intrusion testing was performed for the influence of marine organism ingress structures on the upstream basin. The results of the testing showed that the marine ingress structures should be very modest in size if salinity intrusion problems are to be avoided. The flood control testing suggested that the optimum location of the increased flow capacity should be near the mouth of the primary tributary, the Mermentau River, or else extensive channelization would have a accompany an alternate location.

Lin, Hsin-Chi J. (1992). Houston-Galveston Navigation Channels, Texas Project; Report 2, Two-Dimensional Numerical Modeling Of Hydrodynamics, Technical Report HL-92-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Houston-Galveston Channel Project consists of about 65 miles of deep-water channels leading from the Gulf of Mexico to the Houston Turning Basin at the head of navigation and Galveston Channel, a side channel from Bolivar Roads to Galveston Harbor. The present channel dimensions are 400 ft wide and 40 ft deep at the mean low tide for most of the channel. The Galveston Channel is 1,125 ft wide and 40 ft deep at the mean low tide.

This study used the TABS-MD numerical modeling system to simulate water levels and currents of different channel design conditions for Houston-Galveston navigation channels. These hydrodynamic conditions were used in a separate ship simulator study.

Water level measurements at six tide gages and velocity measurements taken during a 14-hr survey on 18-20 July 1990 at five current stations were used to verify the model. A different subset of water levels from 20-22 November 1990, were used to further verify the model.

The verified model was used to simulate the hydrodynamics for the existing and two proposed channel configurations of the Houston Ship Channel and Galveston Channel. The peak ebb and flood currents and water levels for each design were used as computer files for use in the ship simulator study.

Comparisons of existing channel velocities with those for Phase I and Phase II of the project indicate slight increases in the lower part of Houston Ship Channel.

Lin, Hsin-Chi J., and Richards, David R. (1993). Numerical Model Investigation Of Saugus River And Tributaries, Massachusetts, Flood Damage Reduction, Technical Report HL-93-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Saugus and Pines Rivers estuary is located along the Atlantic coast approximately 10 miles north of Boston, MA. Because of the topography and hydraulics of the Saugus and Pines river basins, a big storm event creates a significant flooding in the areas along the Saugus and Pines Rivers.

A plan was developed by the U.S. Army Engineer Division, New England, to provide flood damage reduction against the Standard Project Northeastern event. The principal component of this plan is construction of tidal floodgates at the mouth of the Saugus River.

The objectives of this study were to use the TABS-MD numerical modeling system to (a) provide upstream and downstream boundary conditions for testing the proposed floodgate plan in a physical model study; (b) determine the impacts caused by breaching of the I-95 embankment at the east branch of Pines River and widened Pines River openings in the I-95 embankment; and (c) evaluate the impacts of floodgate structure on basin tide levels, circulation patterns, and storm surges and sedimentation and the effect of sea level rise on these responses.

Since the proposed floodgate area has not experienced sediment problems, the sediment study was focused on a sensitivity analysis of model parameters. A 24-hr simulation was used to indicate any significant change in sediment deposition and scour pattern in the study area.

The RMA-2V model was successfully verified to limited field measurements including a 3-day field survey of water levels at nine tide gages and a 14-hr survey of velocity measurements at nine current stations. The comparisons of the computed water levels and velocities to field measurements were good.

Breaching of the abandoned I-95 embankment and widening the Pines River opening on I-95 will increase tidal flow in marshy areas. The water levels in marshy areas will increase about 0.5 ft at the peak tide under a spring tide condition. The time lag of the peak water levels between the Broad Sound and upper marshy areas was reduced from 2 hr to 1 hr.

The proposed floodgate will not cause significant change of water levels in the Pines and Saugus Rivers under the normal tide conditions. It will protect the study areas from flooding during the storm events.

The water levels in the marshy areas under Plan 2C+7 will increase about 1.0 ft at the peak flood tide and ebb tide for the 1-ft rise in sea level.

The proposed floodgate will not alter the sediment deposition or scour pattern in the estuary under the normal tide condition, but local scour near the piers may occur.

Lin, H. C., Jones, N. L., and Richards, D. R. (1991). Microcomputer-Based System For Two-Dimensional Flow Modeling. Proceedings of the 1991 National Conference on Hydraulic Engineering, Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 528-533.

An integrated, microcomputer-based system has been developed for simulation of two-dimensional, unsteady, free surface flows. The system consists of a finite-element mesh generation code, a 2-D hydrodynamic code, and graphical post-processors. The mesh generation code was specifically designed for interactive construction of irregular meshes and automatic generation of input files to the hydrodynamic code. The hydrodynamic code was adapted from RMA-2 in the TABS-2 system of models. Graphical displays of water surfaces and velocities are presented. The microcomputer-based system provides engineers with a tool that can be applied to various studies of rivers, lakes, and estuaries. System usage and benchmarks for Macintosh and MS-DOS machines is provided. It provides economical and user-friendly desktop applications for most free surface flow problems.

Lin, H. J., Martin, W. D., and Richards, D. R. (1990). Dredging Alternatives Study, Cubits Gap, Lower Mississippi River; Report 2, TABS-2 Numerical Model Investigation, Volumes I and II, Technical Report HL-90-20, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents results from the numerical model investigation whose primary objective was to determine the best method to control shoaling in the navigation channel between Cubits Gap and Head of Passes. The secondary objective was to evaluate the best design configuration for a structural dike plan located at Cubits Gap and the ability of these designs to return the flow distribution to its historical levels.

Several plans were proposed by the US Army Engineer District, New Orleans, and local shipping interests to alleviate the recurrence of these shoaling conditions. They included a sediment trap, advance maintenance, and additional training structures. The first two addressed shoaling problems in the reach between Cubits Gap and Head of Passes. The latter addressed shoaling and flow distribution in Cubits Gap.

This investigation used the TABS-2 finite element numerical model RMA-2V for hydrodynamic analysis and STUDH for sediment transport computation. A large-flow 87-day hydrograph was used to determine the performance of each plan.

Results from the sedimentation modeling showed that the best nonstructural plan was advance maintenance. It provided a smaller quantity of shoaling than the sediment trap plan and affected a smaller area of the navigation channel. Both nonstructural plans, however, would increase the channel shoaling rate compared to existing conditions. For the structural plan, Plan 1 with a 2,800-ft-long

angle dike and 800-ft-long headland dike provided the least amount of shoaling of any plan tested. All three dike plans tested would result in a substantial reduction in channel shoaling. Results from the hydrodynamic modeling showed that dike plan 1 returned the flow distribution at Cubits Gap to the amount expected with the supplement II works in place. This study did not address long-term sedimentation effects within Cubits Gap. If one of the structural plans is selected for implementation, a detailed study in the vicinity of Cubits Gap is recommended to optimize the performance of the structure.

Lin, H. C., Jorgeson, J. D., Richards, D. R., and Martin, W. D. (1993). A Comprehensive System For Surface Water And Groundwater Modeling. Proceedings of the Federal Interagency Workshop on Hydrologic Modeling Demands for the 90's. James S. Burton, compiler, Water-Resources Investigations Report 93-4018, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA

The U.S. Army Engineer Waterways Experiment Station (WES) and Brigham Young University (BYU) have developed a computer interface system that greatly facilities the pre-processing, execution, and post-processing of watershed, surface water, and groundwater models. The actual computations are made with the models HEC-1 (hydrology), TABS-MD (surface water) and 3DFEMFT (groundwater). A common triangulated irregular network (TIN)-based data structure is used to ensure consistency between hydrology, surface water hydraulics, and groundwater flows. The interface allows easy construction of drainage basins and computes needed input parameters for hydrologic computations and display of hydrographs and flood boundaries. For surface water, the computational meshes and the boundary conditions are easily created and edited. Post-processing tools allow the display of velocity vectors and color-shaded contours of velocity magnitude and water surface elevations in additional to time histories at any point of interest. The groundwater module allows generation and editing of 3-D computational meshes and viewing of results through slices and color contours.

McAnally, W. H. (1987), Hybrid Modeling To Reduce Maintenance Dredging. Third United States-The Netherlands Meeting on Dredging and Related Technology, Charleston, SC, 10-14 September 1984. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The hybrid modeling approach integrates physical modeling, numerical modeling, and analytical methods to produce results that are superior to other methods of predicting harbor sedimentation. The hybrid method has been described previously, but in brief, it applies each method to those processes for which it is best suited. For example, a physical model is used to describe three-dimensional hydrodynamics. Integrating the various solution methods permits the modeler to take advantage of the strengths of each method while avoiding its weaknesses. In this way, more processes can be modeled more accurately. This study indicates that the hybrid modeling approach, using TABS-2, provides an excellent tool for evaluation plans to reduce navigation channel maintenance.

McAnally, W. H., Jr. (1989). Lessons From Ten Years Experience In 2D Sediment Modeling. Sediment transport modeling; proceedings of the International Symposium, New Orleans, August 14-18, 1989. S. S. Y. Wang, ed., American Society of Civil Engineers, New York, 350-355.

Examines the work of the Hydraulics Laboratory, Estuaries Division, on two-dimensional models for sediment transport. Applications of the models include studies of navigation channel sedimentation rates, channel morphology changes, erosion/deposition characteristics of open water dredge spoil disposal and

changes in suspended sediment concentration (dredging or model) and LAEMSED (width integrated vertical model).

McAnally, W. H. (1989). STUDH: A Two-Dimensional Numerical Model For Sediment Transport. Sediment Transport Modeling: Proceedings of the International Symposium, New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 659-664.

TABS-2 water level and flow computations are performed by the generalized numerical model program RMA-2V, salinity and tracer transport computations are performed with RMA-4, and sediment transport computations are performed by STUDH. All three models use the finite element solution technique and can perform computations on the same computational mesh. STUDH performs only sediment transport computations, so hydrodynamics -water levels, current velocities, short period wave heights and periods - must be computed externally and specified as input to STUDH. RMA-2V and STUDH use the same computational mesh and quadratic interpolation functions, so that the water level and velocity field generated by RMA-2V is exactly recreated by STUDH. STUDH calculates transport of sediment by solution of the unsteady, depth-integrated, 2D convection-diffusion equation with source/sink terms representing deposition/erosion processes and bed keeping routines that account for bed structure (thickness, density, strength, etc.) Both cohesive and noncohesive transport are computed.

McAnally, William H., Jr., and Granat, Mitchell A. (1991). Cumberland Sound and Kings Bay, Pre-Trident and Basic Trident Channel Hydrodynamic and Sediment Transport Hybrid Modeling; Volume II: Appendix B, Technical Report HL-90-21, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A previously verified hybrid modeling system (coupled physical and numerical models) of the Kings Bay/Cumberland Sound estuarine system was used to investigate hydrodynamic and sedimentation variations associated with Trident channel expansion. Although not an explicit objective of the modeling efforts, tidal effects were examined. The tested plan condition was predicted by the models to result in higher high water and mid-tide level elevations in both physical and numerical models. Variations were close to, but greater than, model detection limits. Comparison of low-water elevations between the models was inconsistent.

This appendix specifically addresses the issue of tidal changes in a compact format. Pertinent information is compared with field observations and analytical considerations.

Based on the presented information, it is concluded that tide range will probably not change as a result of Trident channel improvements. Mean water level in Cumberland Sound may increase a small amount, less than the normal annual variation in mean sea level. It will be extremely difficult to detect any change until data have been collected for several years.

McAnally, W. H., and Stewart, J. P. (1982). Hybrid Modeling Of Estuarine Sedimentation. Applying research to hydraulic practice, proceedings of the conference, Jackson, MS, August 17-20, 1982. P. E. Smith, ed., American Society of Civil Engineers, New York, Session 8A, 408-417.

A hybrid modeling method using physical and numerical models in an integrated solution method was developed for use in solving estuarine sedimentation problems. The method was applied to the Columbia River estuary with a large

physical model, finite element numerical models RMA-2V and STUDH, a finite difference wave propagation model and several analytical techniques.

McAnally, W. H., Jr., and Thomas, W. A. (1980). Finite Element Models In A Hybrid Model Study Of Estuarine Sedimentation. Finite elements in water resources; preprints of the Third International Conference, Oxford, MS, May 19-23. University of Mississippi, University, MS.

This paper described how two finite element models fit into a hybrid solution method, and discussed experience gained in their application. Water surface elevation, current velocity, and salinity (in three dimensions) are measured briefly at a number of points in a physical model of the estuary. These measurements are used to drive a finite element numerical model for hydrodynamics-RMA-2. Output from RMA-2 and other models as required (e.g., a wind-wave propagation model) drives a two-dimensional finite element numerical model for sediment transport-STUDH. The several models are connected and complemented by a data management system and several pre- and post-processor computer codes. Present criteria for limits on element sizes, shapes, and time steps appear to be lacking. Rules of thumb and previous experience with what works and what does not are valuable guides, but practical, production-oriented model applications generally require that meshes be stretched to the limit in order to stay within time, cost, and computer resources. A related need is for continuing improvement in computational efficiency-a popular area of endeavor. Recent work made the finite element method competitive with other methods, but further improvements are a necessity.

McAnally, W. H., Berger, R. C, Teeter, A. M. (1993). Three-Dimensional Numerical Modeling For Transport Studies. Proceedings, National Conference on Hydraulic Engineering, San Francisco, CA. American Society of Civil Engineers, New York, 2, 2141-2146.

Modeling three-dimensional transport of salinity and sediments in estuarine flows requires that hydrodynamics be accurately modeled with sufficient precision to describe the advection and turbulent diffusion of salinity and sediments. These demands are considerably more stringent that those required for modeling water levels and discharges. Application of the model RMA10-WES and TABS-MD system of multi-dimensional models to San Francisco Bay salinity and sediment transport and Galveston Bay salinity illustrates the challenges involved. Residual flows in these bays reflect both density-driven flows, which are strongly three-dimensional, and tidal pumping, which are weakly three-dimensional, and tidal pumping, which is weakly three-dimensional. Asymmetry in bed stresses combined with these residual flows to induce three-dimensional sediment fluxes that may or may not be consistent with the residual flows.

McAnally, William H., Jr., Brogdon, Noble J., Jr., and Stewart, J. Phillip. (1983). Columbia River Estuary Hybrid Model Studies; Report 4, Entrance Channel Tests, Technical Report HL-83-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A hybrid modeling approach using a fixed-bed physical model, numerical models, and analytical techniques was used to study navigation channel shoaling at the mouth of the Columbia River. Sixteen plans for reducing channel maintenance dredging at the existing 48-ft depth and at 55- and 60-ft depths were tested. Effects of the plans on tides and currents were found to be subtle. Non-deepening plans had minor effects on salinity intrusion while channel deepening increased salinities by 1 to 6 ppt up to about mile 18. Only one structural

plan reduced shoaling below base conditions for the 48-ft channel. Channel deepening increased shoaling considerably.

McAnally, William H., Jr., Brogdon, Noble J., Jr., Letter, Joseph V., Jr., Stewart, J. Phillip, and Thomas, William A. (1983). Columbia River Estuary Hybrid Model Studies; Report 1, Verification Of Hybrid Modeling Of The Columbia River Mouth, Technical Report HL-83-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Columbia Hybrid Modeling System was applied to the mouth of the Columbia River estuary to evaluate alternatives for reducing navigation channel maintenance dredging. The hybrid modeling method using a physical hydraulic model, analytical techniques, and various numerical models in an integrated solution method that takes advantage of the strengths of each technique while avoiding its weaknesses. The methods accounted for the effect of tides, freshwater runoff, wind waves, and littoral currents on sediment transport, deposition, and erosion. The models were verified to satisfactorily reproduce observed prototype behavior.

McAnally, William H., Jr., Letter, Joseph V., Jr., Stewart, J. Phillip, Brogdon, N. James, Jr., Anthony, Thomas W. (1984). Columbia River Hybrid Modeling System, Journal of Hydraulic Engineering 110(3), 300-311.

A hybrid modeling method for predicting waterway sedimentation was developed and applied to the Columbia River Estuary. The method uses physical hydraulic models, two-dimensional (2-D) numerical models, and analytical techniques in an integrated solution scheme. The hybrid modeling system used to study the Columbia consisted of a large physical model of the estuary, RMA-2V, a depth-integrated numerical model for sediment transport, and a collection of analytical methods. By using each model to address those phenomena that it is best able to describe, an improved modeling technique is created.

McAnally, W. H., Letter, J. V., Stewart, J. P., Thomas, W. A., and Brogdon, N. J. (1984). Application Of Columbia Hybrid Modeling System, Journal of Hydraulic Engineering, American Society of Civil Engineers, 110(5), 627-642.

Describes application of the Columbia Hybrid Modeling System to navigation shoaling problems at the mouth of the Columbia River Estuary, U.S.A. A physical model was used for tidal elevations current speeds and directions at multiple depths and salinity concentrations. The numerical hydrodynamic model RMA-2V was used in conjunction with the physical model. Outlines specification of boundary conditions (slip flows, water surface elevations at nodes etc.). Describes time step and iteration procedures, wave analysis and computation of long shore (littoral) currents. Five events were used for verification of the model. Sedimentation modeling used the STUDH model. Examines some limitations of the methods used, notably two-dimensional treatment of sediment transport. Compares model and prototype dredged volumes, and shoaling pattern (scour and fill).

McAnally, William H., and Berger, R.C. (1997). Salinity Changes in Pontchartrain Basin Estuary Resulting from Bonne Carre Freshwater Diversion, Technical Report CHL-97-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Numerical model experiments were performed to predict salinity changes that will occur in the Lake Pontchartrain basin estuary, Louisiana and Mississippi, as a result of proposed Mississippi River freshwater diversions through the Bonnet Carre spillway near New Orleans. One purpose of the diversion is to reduce

salinities in the Biloxi Marshes by 2 to 8 parts per thousand (ppt) in order to improve oyster productivity. A range of monthly salinities has been identified as the desired product of the project. Those salinities, called the Chatry salinities in this report, consist of a narrow band of optimum salinities and a somewhat wider band of range limits.

A time-varying, three-dimensional numerical model of the estuary was constructed using the U.S. Army Corps of Engineers TABS-MD modeling system. The modeled area included Lakes Maurepas, Pontchartrain, and Borgne, Biloxi Marshes, and a portion of Chandeleur Sound plus connecting waterways of Mississippi River-Gulf Outlet (MRGO), Inner Harbor Navigation Canal, Gulf Intracoastal Waterway, Chef Menteur, and The Rigolets. All major tributary freshwater flows were simulated, as were tides at the Gulf of Mexico boundary and winds. The model computed instantaneous water levels and current velocities and salainities in three spatial dimensions throughout the area modeled. The model was verified to satisfactory reproduce hydrodynamic behavior observed in the natural system in 1982 and 1994.

Four conditions were modeled for April through August of a typical year: a Base condition with no diversion, Plan RT with freshwater diversions up to 20,000 cfs, Plan MBP5 with freshwater diversions up to 8,500 cfs, and Plan LBC1, with no freshwater diversions but with the connections between the MRGO and Lake Borgne closed.

The numerical model results were used to construct a simple regression equation that relates Biloxi Marsh salinities at a point to freshwater flows from the natural tributaries plus the diversions. The equation was then used to develop other diversion schedules that offered various salinity reduction scenarios.

The following conclusions and recommendations are drawn from the work:
a. The estuary responds very slowly to changes in freshwater inflow to Lake Pontchartrain. For example, in the Biloxi Marshes salinity effects are noticeable within 30 days of a change in flow, but the peak effect occurs at about 60 days, and a noticeable residual effect remains at 120 days.
b. The MRGO is a significant contributor to the salinity regime in the Lake Pontchartrain to Biloxi Marshes area, primarily via MRGO connections to Lake Borgne.
c. A Bonnet Carre structure discharge capacity of about 30,000 cfs is required to achieve the desired spring salinity of about 6 ppt about every other year at Line 2, a location in the Biloxi Marshes identified as the target location in the General Design Memorandum (GDM). However, any year in which that low salinity is achieved (either by diversion or natural freshening) will be fresher than desired in the subsequent 2 months because of the slow response time of the system.
d. The plans considered here will reduce salinities at Line 2 in the Biloxi Marshes for a typical year (50 percent exceedance flows). Specifically, compared to the Base, or no diversion, condition, the plans had the following effects on salinities at about the center of Line 2:

(1) Plan RT (up to 20,000 cfs) reduced salinities up to 4.2 ppt during April-August. It reduced salinities to Chatry optimum values or less for 10 months out of 12.
(2) Plan MBP5 (up to 8,500 cfs) reduced salinities up to 3.4 ppt during April-August. It reduced salinities to Chatry optimum values or less for 9 months out of 12.
(3) Plan LBC1 (closure of lake Borgne-MRGO connections) reduced salinities up to about 2 ppt during April-August.

e. Other potential diversion schedules can be devised and salinity reduction approximated by the simple equation developed in this report without additional model experimentation in order to balance achievement of salinity goals with other criteria. However, any plan devised by that method should be subjected to model experimentation before design is complete and before an operational plan is designed.
f. Control of salt flux up MRGO and through the outlets can contribute significantly to achieving Biloxi Marsh salinity goals. Possible control methods are discussed in Chapter 5 of this report. By extension, it may be possible to combine MRGO salt contributions with smaller diversions (e.g., MBPJ) to approach target salinities at Line 2.
g. The basin response conclusions in item d imply that a Bonnet Carre diversion schedule must be statistically based. Before construction of a project, the plans reported here must be replaced with a diversion operational plan that takes into account antecedent conditions and a stochastic forecast of future tributary inflows. Such an operational plan will produce some years fresher than desired and some years saltier than desired, as described in the GDM. Chapter 5 of this report suggests an approach for developing such an operational plan.

MacArthur, Robert C., Pennaz, James, Freeman, Gary E., Weissinger, Lisa L., and King, Ian P. (1991). Enhanced Multi-Dimensional Modeling Of Marshes And Wetlands. Proceedings of the 1991 National Conference on Irrigation and Drainage, Honolulu, HI, July 22-26, 1991. American Society of Civil Engineers, New York, 794-800.

This paper summarizes the verification and application of a two-dimensional finite element model capable of simulating the complex circulation characteristics in marshes and wetlands for a variety of boundary and flow conditions. The new 'Marsh Elements and Culvert-Weir' version of computer program RMA-2V includes capabilities to simulate marsh hydrodynamics and culvert and weir flow along the margins of a marsh or wetland.

McCollum, Randy A., and Donnell, Barbara P. (1994). Claremont Terminal Channel, New York Harbor, Technical Report HL-94-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A ship simulator investigation of Claremont Terminal Channel was performed to determine the effects on ship handling of the proposed widening and deepening of the existing channel from approximately 150 ft to 300 ft and 27 ft mlw to 34 ft mlw, respectively. A hydrodynamic model study of the same area was conducted in support of the ship simulator investigation to supply current fields for the existing channel and proposed channel modifications. This report will describe the ship simulator investigation, it's conclusions, and recommendations. Appendix A will describe the hydrodynamic verification and numerical simulation of the existing Claremont Channel bathymetry and two proposed channel design plans. Appendix B describes the governing equations of the TABS-MD numerical modeling system.

Martin, William D., and Berger, R. C. (1989). Southwest Pass Training Structure Alternatives. Proceedings of the 1989 National Conference on Hydraulic Engineering, New Orleans, LA, August 14-18, 1989. American Society of Civil Engineers, New York, 969-974.

The U.S. Army Engineer Waterways Experiment Station system of computer programs, TABS-2, was utilized to evaluate various structural plans for increasing channel velocities and sediment transport capacity in the lower Southwest Pass of the

Mississippi River. The study area was limited to the lower 4 miles of the Pass. A high flow representing 900,000 cubic feet per second at Venice, Louisiana, was selected for analysis. A high resolution finite element mesh that allowed detailed evaluation of velocity vectors was used to analyze seven alternative plans. This relatively quick and inexpensive analysis technique resulted in an optimal structural plan which provided maximum channel velocities at a minimal cost.

Melidor, Avenant, Thomas, W. A., and McAnally, W. H. (1984). Numerical Model Of Mississippi River at Lock and Dam 26. Water for Resource Development, Proceedings of the Conference, Coeur d'Alene, ID, August 14-17, 1984. American Society of Civil Engineers, New York, 64-66.

Replacement work was initiated in November 1979. The first stage cofferdam constricted about half of the river channel. As a result, the flow velocity at the construction increased causing considerable erosion, and the river bed dropped about 20 ft during the period of May 1981 to May 1982. The St. Louis District had the Waterways Experiment Station (WES) conduct a physical, movable-bed, hydraulic model study of the scour problem. In addition, the district applied the TABS-2 Numerical Modeling System to the problem with assistance from WES Hydraulics Laboratory personnel. The results of the TABS-2 study are reported. TABS-2 is a system of generalized computer programs and utility programs that are used to model open channel flows and transport processes, including sedimentation.

Pankow, Virginia R. (1988). San Francisco Bay: Modeling System For Dredged Material Disposal And Hydraulic Transport,, Technical Report HL-88-27, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A combination of physical and numerical models was used to simulate the hydrodynamic, circulation, and sediment transport characteristics of San Francisco and San Pablo bays. This simulation was done in response to a request by the U.S. Army Engineer District, San Francisco, to develop a modeling tool that can define the fate of dredged material disposed at the Alcatraz disposal site.

Tide and current velocity data from the San Francisco Bay-Delta physical model were used to verify the vertically averaged hydrodynamic model, RMA-2V (Two-Dimensional Model for Free Surface Flows). This model was used to generate the velocity field for a dredged material disposal model, DIFID (Discharge From an Instantaneous Dump). The suspended sediment concentrations from DIFID and the geometry and hydrodynamic data from RMA-2V were used in the sediment transport model, STUDH (Sediment Transport in Unsteady Two-Dimensional Flows, Horizontal Plane), to establish sediment transport and dispersion patterns around the Alcatraz disposal site in central San Francisco Bay. Two model meshes were developed for this study: a comprehensive or global mesh of the entire system, and a more detailed inset mesh of the Alcatraz disposal area.

The modeling system has its capabilities and applications. However, the results are just reasonable simulations, not fully verified ones. Each of the numerical models, RMA-2V, DIFID, and STUDH, has individual capabilities and limitations, the greatest of which is the two-dimensional approximation of a three-dimensional phenomenon. The vertically averaged velocities and sediment fields will mask two-layer flow and other three-dimensional processes. Even with this simplification, the model results are useful in estimating the short- and long-term fates of sediments released during a disposal operation.

Appendix A describes the TABS-2 modeling system in which RMA-2V and STUDH belong, and Appendix B gives details of the numerical model DIFID.

Pokrefke, T. J., Jr., Nickles, C. R., Raphelt, N. K., Trawle, M. J., and Boyd, M. B. (1995). Redeye Crossing Reach, Lower Mississippi River; Report 1, Sediment investigation, Technical Report HL-95-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The sedimentation study conducted on the Redeye Crossing Reach of the Mississippi River about 3 miles downstream of Baton Rouge, LA, was a combination of numerical and physical movable-bed model studies to aid in the development of a satisfactory dike design for this reach. A two-dimensional numerical model, TABS-2, was used to predict the reduction in dredging that could be anticipated with the original dike design and subsequent modifications. Those modifications included changing the length, height, location, and number of spur dikes. The plans investigated addressed the required dike plan to maintain the existing 40-ft navigation channel through the reach and an enhancement of that plan to provide a 45-ft channel to be developed in the near future.

Since no dikes presently exist in this portion of the Mississippi River, the physical movable-bed model study was also conducted to take advantage of the capabilities of both types of models. Thus the overall study allowed use of the numerical model to screen plans and the physical model to address detailed impacts of the plans. The physical model was constructed to a horizontal scale of 1:240 and a vertical scale of 1:200 including the river channel and overbank areas to the adjacent levees. During the overall testing program the numerical model was used to refine and test dikes plans. The dike plans deemed most successful from the numerical sedimentation model were also tested on the physical model.

Raphelt, Nolan K., Trawle, Michael J., Weissinger, Lisa L. (1991). River Dike Design Using A Numerical Model Approach. Proceedings of the 1991 National Conference on Hydraulic Engineering, Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 435-440.

The preliminary design of a dike field at Redeye Crossing on the Mississippi River (Baton Rouge, Louisiana) is discussed. The TABS-2 modeling system was used to develop a two dimensional sediment transport model of the Mississippi River from River Mile 228 downstream to 206. Numerical model results are presented. The numerical modeling effort included dynamic simulations two years long to evaluate the impact of proposed dike field layouts on dredging requirements. An assessment of the model's applicability to the design of dike fields consisting of submerged rock dikes and model limitations encountered during the study are presented.

Richards, D. R. (1988). New Haven Harbor numerical model study, Technical Report HL-88-24, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents the results from a numerical model study of the impacts of deepening and widening the approach channels and inner turning basin in New Haven Harbor, CT. Results from the study were intended to determine changes in circulation, which might affect valuable oyster resources, and to form the current fields needed to provide a detailed ship simulation study of the navigation improvement project. The US Army Corps of Engineers numerical modeling system, TABS-2, was used to predict the changes that might occur to circulation patterns in New Haven Harbor and portions of Long Island Sound. Currents were predicted in the navigation channel as well as in distant shallow

regions where there is a significant shellfish fishery. Results from the numerical model study indicated that there were perceptible changes in the circulation patterns but that the magnitude of the changes was very small. In most cases, base-minus-plan differences in the currents were less than 0.1 fps. The largest differences occurred in the deepened channels, away from the shallow oyster bed areas. No tide differences were detected between base and plan.

Richards, D. R. (1990). Flow Separation Around A Solitary Dike; Eddy Viscosity And Mesh Considerations. Hydraulic Engineering: Proceedings of the 1990 National Conference, San Diego, CA, July 30-31, 1990. American Society of Civil Engineers, Boston Society of Civil Engineers Section, Boston, MA, 2, 867-872.

The hydrodynamic model RMA-2V has been verified on a variety of global circulation studies. These studies rarely involved separated flow patterns around sudden expansions or contractions. This paper presents results from numerical and physical studies of separated flow around a solitary dike. Particular emphasis is placed on eddy viscosity and mesh refinement issues as they pertain to numerical model accuracy.

Richards, David R., Athow, Robert F., and Anderson, Jerry L. (1987). Numerical Modeling Of Estuarine Training Structure Effects On Navigation Channel Performance. Coastal Zone '87: Proceedings of the Fifth Symposium on Coastal and Ocean Management, Seattle, WA, May 26-29, 1987. American Society of Civil Engineers, New York, 1575-1587.

A two-dimensional, vertically averaged, numerical modeling technique is presented to analyze estuarine training structure performance. The technique consists of using the US Army Corps of Engineers TABS-2 numerical modeling system with special emphasis on high-resolution grids and rigorous model verification procedures. Physical model experimental results are compared with the results obtained from the numerical model simulation for purposes of model verification. A typical estuarine reach of the Columbia River is simulated in the numerical model, modeling both impermeable and permeable dike fields. Excellent numerical simulation of the expected velocity fields was achieved. It is concluded that some secondary currents can be successfully simulated using the required resolution.

Sanchez, Jose A., and Roig, Lisa C. (1997). Hydrodynamic and Sediment Transport, Mill Cove, St. Johns River, Florida, Numerical Modeling Study, Technical Report CHL-97-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The U.S. Army Engineer District, Jacksonville, is investigating how to improve tidal flushing in Mill Cove, lower St. Johns River, Florida, to maintain water quality and to prevent excessive sedimentation. Four plans have been proposed to reshape the shoreline within the cove. One additional proposed plan will also modify the bathymetry in the area. RMA2-WES, a two-dimensional, vertically averaged hydrodynamic model, was used to compare the circulation patterns that occur in the present-day Mill Cove against the circulation patterns that would result from the five plan configurations. Sediment transport was simulated using SED2D-WES, a two-dimensional, vertically averaged model of sediment advection and dispersion in the water column, with the channel bed acting as a source and/or sink for sediment as it deposits and erodes. Currents and tides were compared to prototype data to validate the numerical model. The study addressed changes within Mill Cove as well as any influence these changes had in the navigation channel.

Smith, Tamsen M., McAnally, William H., Jr., and Teeter, Allen M. (1987). Corpus Christi Inner Harbor Shoaling Investigation, Technical Report HL-87-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A combination of numerical models was used to test alternatives for shoaling prevention in Corpus Christi Harbor, Texas. The vertically averaged model system, TABS-2, was used to simulate contributions of sediments by bay waters to the sediment load. The laterally averaged estuarine model, LAEMSED, was used to simulate density currents in the channel and sedimentation that occurs at the harbor entrance.

Applications of the models testing advance maintenance, removal of industrial discharges and withdrawals, advance maintenance in conjunction with a sill, and movement of the disposal areas showed a 20 percent decrease in shoaling as a result of industrial activity removal, a 75 percent decrease in sediments entering the bay channel due to disposal area relocation, and practically no effect on shoaling rates resulting from advance maintenance.

Appendix A presents the results of a reconnaissance survey on shoaling conditions in Corpus Christi Harbor. Appendix B describes the TABS-2 numerical modeling system, and Appendix C describes the theoretical aspects of LAEMSED.

Soong, Ta Wei, and Bhowmik, Nani G. (1991). Two-Dimensional Hydrodynamic Modeling Of A Reach Of The Mississippi River In Pool 19. Proceedings of the 1991 National Conference on Hydraulic Engineering, Nashville, TN, July 29-August 2, 1991. American Society of Civil Engineers, New York, 900-905.

A depth-integrated finite-element model (RMA-2V) was applied on a section of the Upper Mississippi River to study the hydraulic characteristics of the flood plain-river system. The area that has been modeled is called 'Montrose Flats.' Aquatic vegetation is abundant at this location, and the flow structure needs to be evaluated in order to study the nutrient transport conditions within this area. The present study focused on a large oval eddy that was observed to form in this area near the downstream end of the Devil's Creek delta. Causative factors for this eddy were examined by using this numerical model. Results indicate that the eddy can be simulated by this model and that numerical study is a feasible way to examine the mechanisms of eddy formation.

Stockstill, R. L., Martin, s. K., and Berger, R. C. (1995) Hydrodynamic Model Of Vessel- Generated Currents, Regulated Rivers: Research & Management, Vol 11, 211-225, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The drawdown and return currents of vessels navigating in channels have previously been described by empirical relations or by using physical models. The empirical solutions are generally limited in scope to idealized channel shapes. Physical models are unrestricted in this respect, but have limitations related to expense and scale effects. In this paper, vessel effects are modeled numerically. The vessel’s displacement is represented by a moving pressure field. The movement of the pressure field is spatially varied in time, representing a vessel navigating along a channel. The hydrodynamics are described using the two-dimensional shallow water equations, which are modified to account for the effects of the imposed pressure field. A Petrov-Galerkin finite-element scheme using characteristic-based weighting is used to solve the governing equations. This Petrov-Galerkin test function is specifically designed to model flow fields containing large gradients such as those found in the vicinity of the moving vessel. The numerical results for return flows and water surface elevations are compared with flume results of vessel passages.

Stockstill, Richard L., Berger, R. C., and Nece, Ronald E. (1997). Two-Dimensional Flow Model For Trapezoidal High-Velocity Channels, Journal of Hydraulic Engineering, American Society of Civil Engineers, ISSN 0733-9429/97/0010-0844-0852.

A two-dimensional numerical flow model for trapezoidal high-velocity channels is developed. The model is designed specifically for simulation of flow in channels having sloping sidewalls in which the depth is an unknown variable in the governing equations and therefore the plan view of the flow domain is not known a priori. Solutions are obtained by time stepping from specified initial conditions using an implicit Petrov-Galerkin moving finite-element representation of the governing equations. The moving finite-element model produces a simultaneous solution for the boundary displacement and flow variables. This implementation provides stable solutions for supercritical flow even at relatively large Courant numbers. The model is tested by comparison of simulation results with laboratory data. These data sets serve as a basis for evaluation of the numerical model and should also prove useful to researches in testing other numerical flow models applied to supercritical flow in channels having sloping sidewalls.

Stockstill, R. L. (1997). Implicit Moving Finite Element Model of the 2D Shallow-Water Equations, Moving Boundaries IV, Computational Modeling of Free and Moving Boundary Problems, ed. R.V. Keer and C. A. Brenbbia, Computational Mechanics Publications.

This paper describes a method for determining implicitly, the waterline and flow variables in shallow water. In particular, the shallow-water equations are applied to open channels with sloping sidewalls and dam-break flow over initially dry beds. The domain limits are time dependent in both cases, but only the former has a steady state. Arbitrary Lagrangian-Eulerian descriptions of the two-dimensional shallow-water equations are used to describe the time-dependent waterline formed by the water-surface/channel-bed intersection. The model uses and implicit Petrov-Galerkin moving-finite-element representation of the shallow-water equations. Simultaneous solutions of the two-dimensional shallow-water equations and waterlines are obtained. The implicit approach relaxes time-step size limitations and the Petrov-Galerkin test function provides numerical stability for advection-dominated flows. The model offers a viable means of representing shallow-water flows where the boundary locations are not known a priori.

Stockstill, Richard L. (1995). 2D Modeling of Class B Bridge Flow in Steep Channels, Proceedings of the First International Conference on Water Resources Engineering, American Society of Civil Engineers.

Bridge piers located in flood control channels are classified by the relation of flow depth through the bridge section to critical depth upstream, between, and downstream of the piers. The term Class B flow is applied to conditions in which sub-critical flow approaches the bridge, passes through critical depth at a point along the piers, and then jumps to sub-critical flow or remains supercritical depending on the downstream conditions. The far field dlow upstream of the bridge may be sub-critical or supercritical. The flow studied in this paper are of the Class B type in hydraulically steep channels. The bridge pier constriction chokes the flow producing a hydraulic jump upstream of the piers. The flow downstream of the piers is supercritical. The numerical flow model HIVEL2D is used to simulate the rapidly varied flow. HIVEL2D is a depth-averaged, two-dimensional (2D) flow model designed specifically for flow

fields that contain supercritical and sub-critical regimes as well as the transitions between the regimes. Simulation results are compared with published laboratory data.

Stockstill, Richard L. (1994). Application of a Two-Dimensional Model of Hydrodynamics to San Timoteo Creek Flood-Control Channel, California, Technical Report HL-94-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The San Timoteo Creek, located in southern California, is a tributary of the Santa Ana River and drains portions of the San Bernardino and Riverside Counties. The existing creek has the capacity to protect the surrounding community from approximately a 20-year-frequency flood. The proposed channel improvements will provide a 100-year level of protection. The proposed channel design within the reach studied includes a sediment basin, a concrete weir followed by a converging sidewall chute, a compound horizontal curve, and a bridge pier. This study was initiated because there was concern as to the adequacy of a one-dimensional analysis of the flow conditions within the channel chute. A two-dimensional analysis was deemed necessary to evaluate the chute s influence on the flow conditions in the curve and the curve s impact on the flow conditions at the bridge

The two-dimensional, depth-averaged flow model, HIVEL2D, was used to simulate the flows in the high-velocity channel. This model was chosen because of its ability to simulate supercritical flow and capture shocks such as oblique standing waves. Simulation results indicated that the proposed San Timoteo Channel design and in particular, the San Timoteo Canyon Road bridge, will convey the design discharge (100-year frequency event, 19,000 cfs) in an acceptable manner.

Stockstill, Richard L. (1996). A Two-Dimensional Free-Surface Flow Model for Trapezoidal High-Velocity Channels, Technical Report HL-96-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A two-dimensional free-surface numerical flow model for trapezoidal high-velocity channels is developed. The model addresses common hydraulic features of high-velocity channels including sub-critical or supercritical flow, which may undergo transition from one regime to the other and can be further complicated by the presence of oblique standing waves. The model is designed specifically for simulation of flow in trapezoidal high-velocity channels in which the depth is an unknown variable in the governing equations; therefore, the plan view of the flow domain as delineated by the water surface/bank interface is not known a priori.

Steady state solutions are obtained by time stepping from specified initial conditions using an implicit Petrov-Galerkin moving finite element representation of the governing equations. As the computed flow field evolves from the specified initial flow conditions and initial boundary location to the steady state, the moving finite element model adjusts the location of side boundaries with the depth solution. The algorithm includes a novel method for solving the boundary displacement and the flow variables simultaneously.

Testing of the computational model consists of comparing model results with analytical solutions and laboratory flume data. These tests demonstrate that the numerical model can be used as a tool for the evaluation of trapezoidal high-velocity channel designs.

Stockstill, R. L. (1994). HIVEL2D: A Two-Dimensional Flow Model for High-Velocity Channels, Technical Report REMR-HL-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A numerical flow model, HIVEL2D, has been developed as a tool to evaluate high-velocity channels. HIVEL2D is a depth-averaged, two-dimensional flow model designed specifically for flow fields that contain supercritical and sub-critical regimes as well as the transitions between the regimes. The model is a finite element description of the two-dimensional shallow-water equations in conservative form. Provided in this report are a description of the numerical flow model and illustrative examples of typical high-velocity flow fields that the model is capable of simulating. Model verification is obtained by comparison of simulation results with data obtained from flume studies. Model assumptions and limitations are also discussed.

Teeter, Allen M, Letter, Joseph V. Jr., Pratt, Thad C., Callegan, Christopher J., and Boyt, William L. (1996). San Francisco Bay Long-Term Management Strategy (LTMS) For Dredging and Disposal, Report 2, Baywide Suspended Sediment Transport Modeling, Technical Report HL-96-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Field data analysis was used to examine suspended sediment transport in Central San Francisco Bay, and to develop and verify a two-dimensional numerical fine-grained sediment transport model. This study concerned the dispersion and fate of disposed dredged material in Central San Francisco Bay, California. The 1992 monitoring survey spanned a 2-week period in June, and used three boat-mounted acoustic Doppler current profiling (ADCP) systems to obtain repeated cross-sectional transects near the Golden Gate, the entrance to South Bay, and Richmond Point. Between acoustic transects, water samples were obtained over depth for salinity, total suspended material (TSM) concentration, and particle size determinations. Acoustic backscatter data were used to produce correlated suspended material concentration and flux fields. Discrete measurements were fit to empirical discharge and suspended flux models and integrated over a neap-spring-neap-tidal sequence to estimate net transport.
There was an observed net transport of suspended sediment seaward at the Golden Gate over the neap to spring sampling period. The total net transport was 188x106kg (188,000 metric tonnes) seaward over 14 lunar days. Fluxes during the ebb flows averaged 44 percent greater than the flood flows, and instantaneous strong-ebb TSM fluxes were often more than twice those on flood tidal phases.

Suspended sediment concentration increased during the strongest part of the ebb at all Central Bay sampling ranges. Wind forcing did not appear important to this process. Suspended concentrations quickly returned to normal levels after the passage of peak ebb flows. Spatial variability in the TSM fields was relatively large. The ADCP backscatter intensity measurements correlated well with TSM especially on the Golden Gate range where a broadband unit was employed.

The numerical sediment model reproduced the tidal flux across ranges adequately. Instantaneous TSM concentrations at a point were less well predicted by the model as was temporal variability. The model did not fully capture TSM variability. The model should be a useful tool in predicting general transport patterns in Central Bay.

Thomas, William A., and Heath, Ronald E. (1984) Application of TABS-2 To Greenville Reach, Mississippi River. River meandering, proceedings of the

conference Rivers 1983, New Orleans, LA, October 24-26, 1983. American Society of Civil Engineers, New York, 908-919.

No Abstract

Thomas, W. A., Heath, R. E., Stewart, J. P., and Clark, D. G. (1988). The Atchafalaya River Delta; Report 5, the Atchafalaya River Delta Quasi-Two-Dimensional model of delta growth and impacts on river stages, Technical Report HL-82-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A quasi-two-dimensional sediment movement computer program was verified to historical bed deposition and scour and used to forecast delta growth for the next 50 years. The results are compared with growth rates predicted by several other methods in Report 6 of this series, "Interim Summary Report of Growth Prediction."

Webb, Dennis W., and Daggett, Larry L. (1991). Ship Navigation Simulation Study Brazos Island Harbor 42-Foot Improvement Brownsville, Texas, Technical Report HL-91-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

A real-time ship simulation investigation of the proposed design for deepening and widening the man-made Brazos Island Harbor Channel, Brownsville, TX was conducted. The purpose of this study was to determine if the navigation channel could be deepened from 36 to 42 ft without widening the existing channel width of 200 ft or if the channel required widening to 250 or 300 ft as authorized. A numerical model of the existing ship channel from the Gulf of Mexico to the turning basin at the Port of Brownsville was developed. This model was verified by a member of the Brazos-Santiago Pilots Association. Numerical models of three plans were also developed, one with the existing channel deepened to 42 ft, one with the channel widened to 250 ft and deepened to 42 ft, and the other with the channel widened to 300 ft and deepened to 42 ft. The 250-ft wide channel had a 100-ft wide and 15-ft deep side channel for tow traffic. Tests were run in Brownsville on the US Army Engineer Waterways Experiment Station portable ship simulator.

These tests demonstrated that 250 ft is the optimum width for the Brazos Island Harbor Channel at a depth of 42 ft.